



US009362745B2

(12) **United States Patent**  
**Wu et al.**

(10) **Patent No.:** **US 9,362,745 B2**  
(45) **Date of Patent:** **Jun. 7, 2016**

(54) **POWER STORAGE MODULE AND POWER STORAGE DEVICE**

USPC ..... 307/74  
See application file for complete search history.

(71) Applicant: **Delta Electronics (Shanghai) Co., Ltd.**,  
Shanghai (CN)

(56) **References Cited**

(72) Inventors: **Hong-Yang Wu**, Shanghai (CN); **Xiao Li**, Shanghai (CN); **Wen-Tao Zhan**,  
Shanghai (CN)

U.S. PATENT DOCUMENTS

4,328,429 A \* 5/1982 Kublick ..... H02J 3/38  
307/58  
6,750,391 B2 \* 6/2004 Bower ..... H02S 20/23  
136/244

(73) Assignee: **DELTA ELECTRONICS (SHANGHAI) CO., LTD.**, Shanghai  
(CN)

(Continued)

FOREIGN PATENT DOCUMENTS

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 97 days.

CN 1966975 A 5/2007  
CN 101789620 A 7/2010

(Continued)

(21) Appl. No.: **14/285,650**

OTHER PUBLICATIONS

(22) Filed: **May 23, 2014**

H.S. Hong, "Research on Capacity Configuration and Coordinated Control of Hybrid Energy Storage System for Smoothing Out Wind Power Fluctuations," in China Master's Theses Full-text Database, published on Jul. 15, 2013.

(65) **Prior Publication Data**

US 2015/0069844 A1 Mar. 12, 2015

*Primary Examiner* — Jared Fureman

*Assistant Examiner* — Alfonso Perez Borroto

(30) **Foreign Application Priority Data**

Sep. 10, 2013 (CN) ..... 2013 1 0409995

(74) *Attorney, Agent, or Firm* — CKC & Partners Co., Ltd.

(51) **Int. Cl.**

**H02J 1/00** (2006.01)  
**H02J 1/10** (2006.01)  
**H02J 3/32** (2006.01)

(Continued)

(57) **ABSTRACT**

A power storage module and a power storage device are disclosed. The power storage module and the power storage device include a DC/AC converter, a first power storage element, a second power storage element and at least one DC/DC converter. The first power storage element is coupled to the DC side of the DC/AC converter to form a first power storage branch. The second power storage element is coupled to the DC side of the DC/AC converter to form a second power storage branch. The DC/DC converter is disposed on the first power storage branch or the second power storage branch.

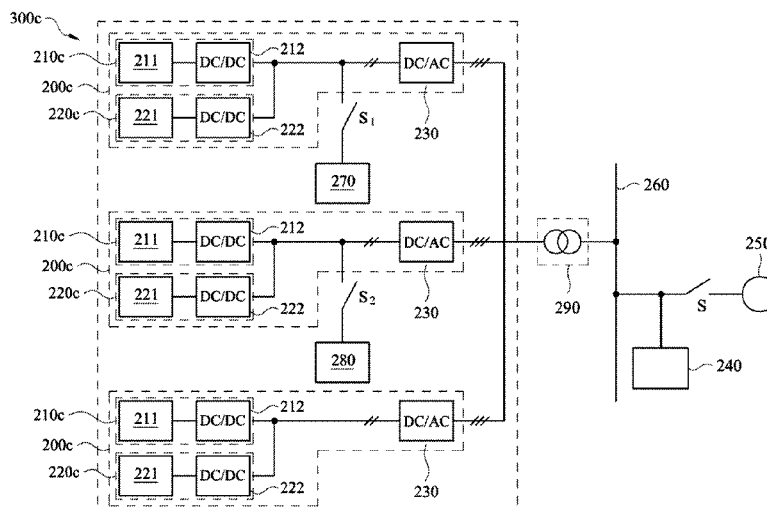
(52) **U.S. Cl.**

CPC . **H02J 1/102** (2013.01); **H02J 3/32** (2013.01);  
**H02J 7/345** (2013.01); **H02J 1/12** (2013.01);  
**Y10T 307/658** (2015.04); **Y10T 307/669**  
(2015.04); **Y10T 307/707** (2015.04)

(58) **Field of Classification Search**

CPC ..... H02J 1/102; H02M 3/04; H02M 7/44

**24 Claims, 11 Drawing Sheets**



# US 9,362,745 B2

Page 2

(51) **Int. Cl.** 2011/0019444 A1\* 1/2011 Dargatz ..... H02H 1/0015  
**H02J 7/34** (2006.01) 363/50  
**H02J 1/12** (2006.01) 2011/0115301 A1 5/2011 Bhavaraju et al.  
2011/0260690 A1\* 10/2011 Kojori ..... H02J 3/32

(56) **References Cited** 2012/0033466 A1\* 2/2012 Moussaoui ..... H02J 3/385  
320/134  
363/65

## U.S. PATENT DOCUMENTS

2004/0125618 A1\* 7/2004 De Rooij ..... H02J 1/102  
363/17  
2007/0138792 A1\* 6/2007 Liu ..... H02J 4/00  
290/1 A  
2009/0179500 A1\* 7/2009 Ragonese ..... H02J 1/10  
307/82  
2009/0279336 A1\* 11/2009 Erdman ..... H02M 7/53875  
363/131  
2010/0133911 A1\* 6/2010 Williams ..... G05F 1/67  
307/82

## FOREIGN PATENT DOCUMENTS

CN 102069721 A 5/2011  
CN 102237691 A 11/2011  
CN 102983589 A 3/2013  
CN 103219899 A 7/2013  
CN 103259287 A 8/2013  
WO 2007/037972 A2 4/2007

\* cited by examiner

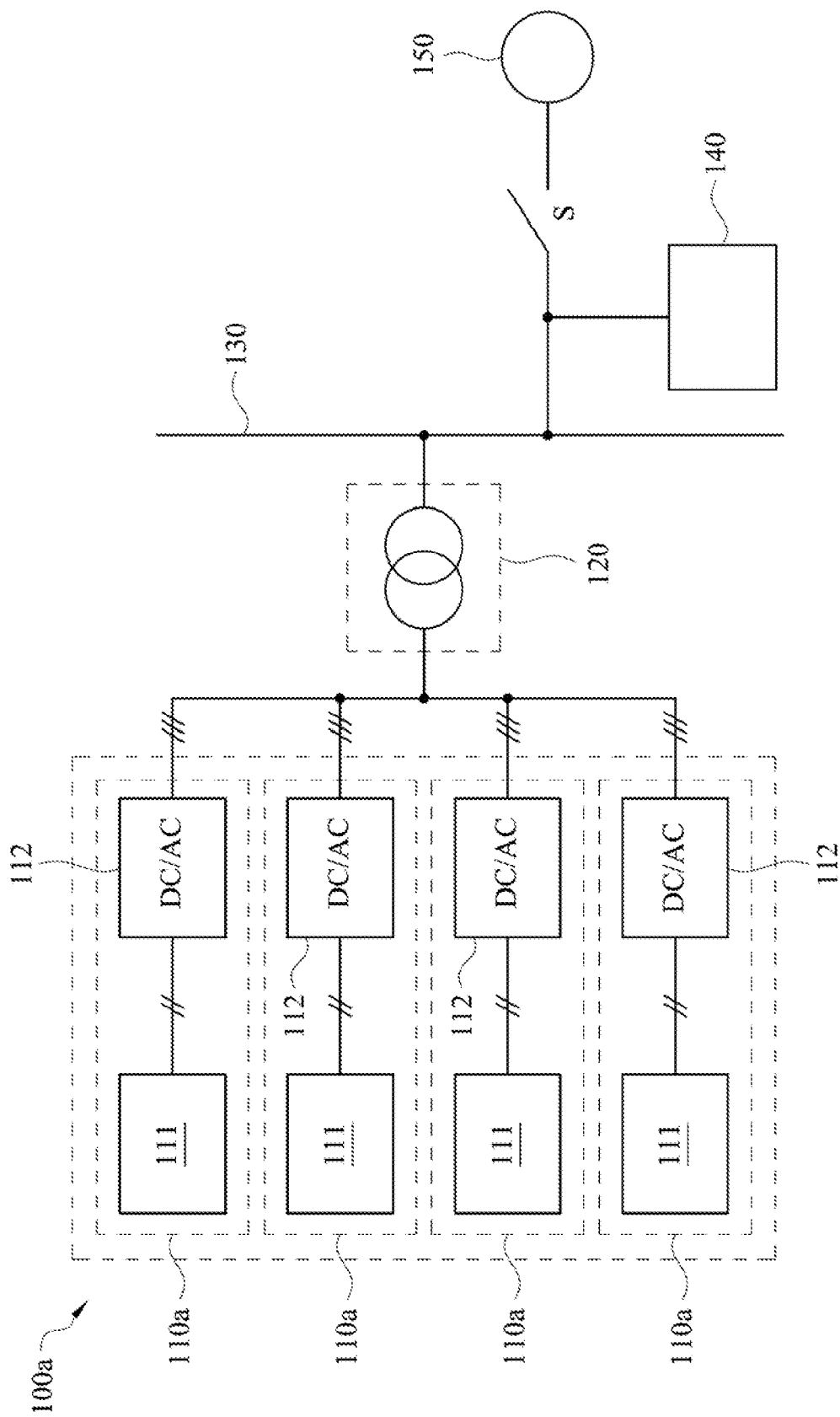


Fig. 1a  
(Prior Art)

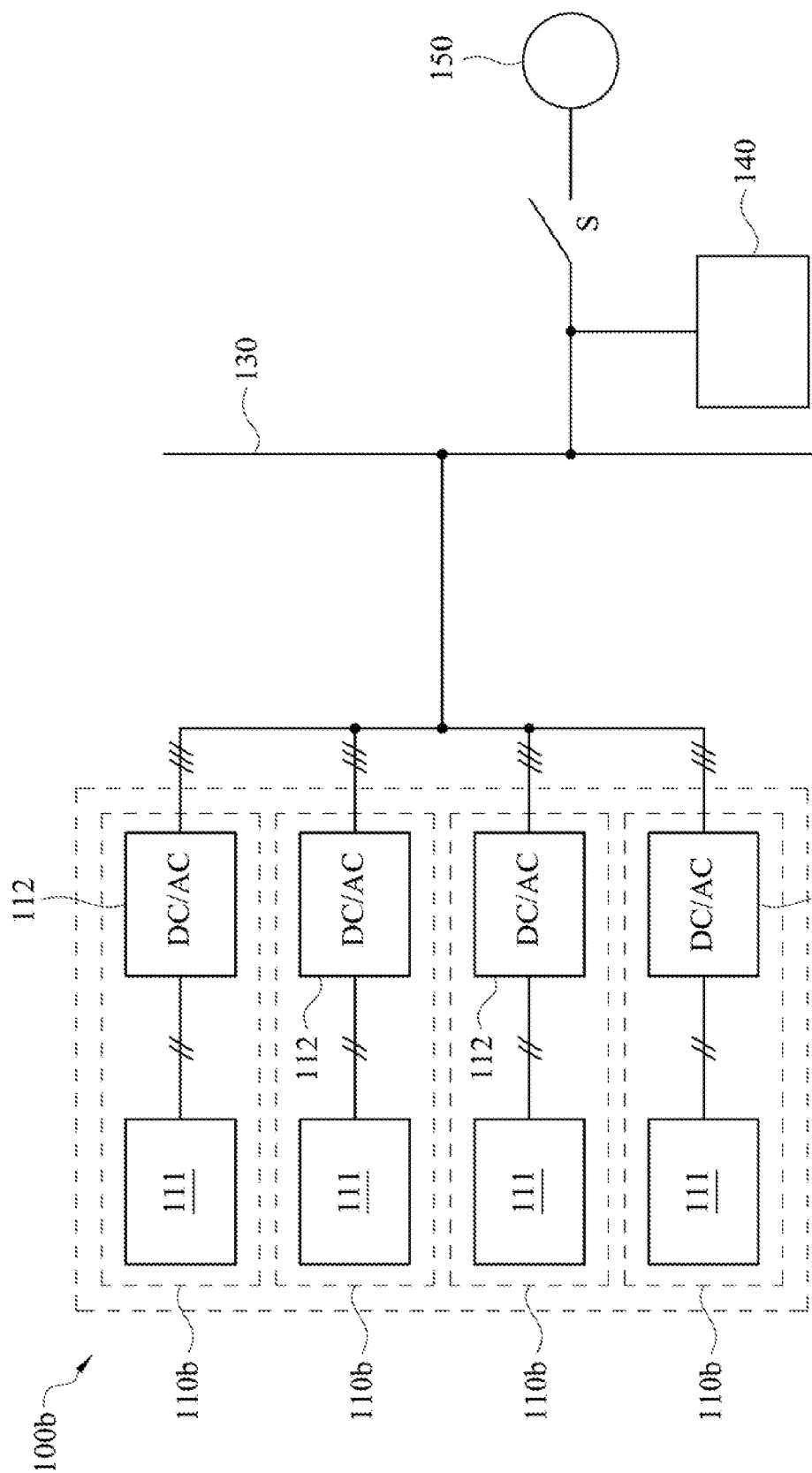


Fig. 1b  
(Prior Art)

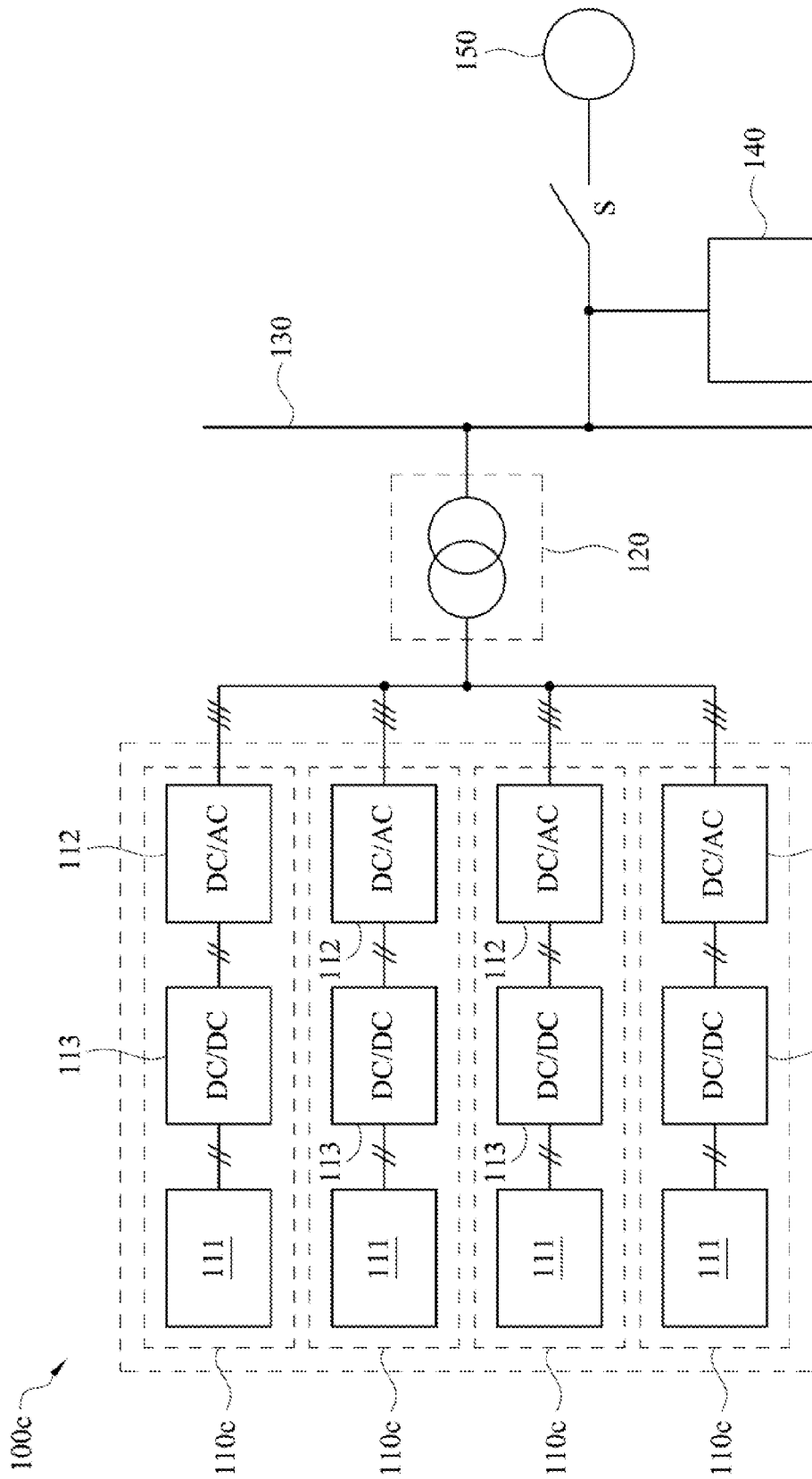


Fig. 1c  
(Prior Art)

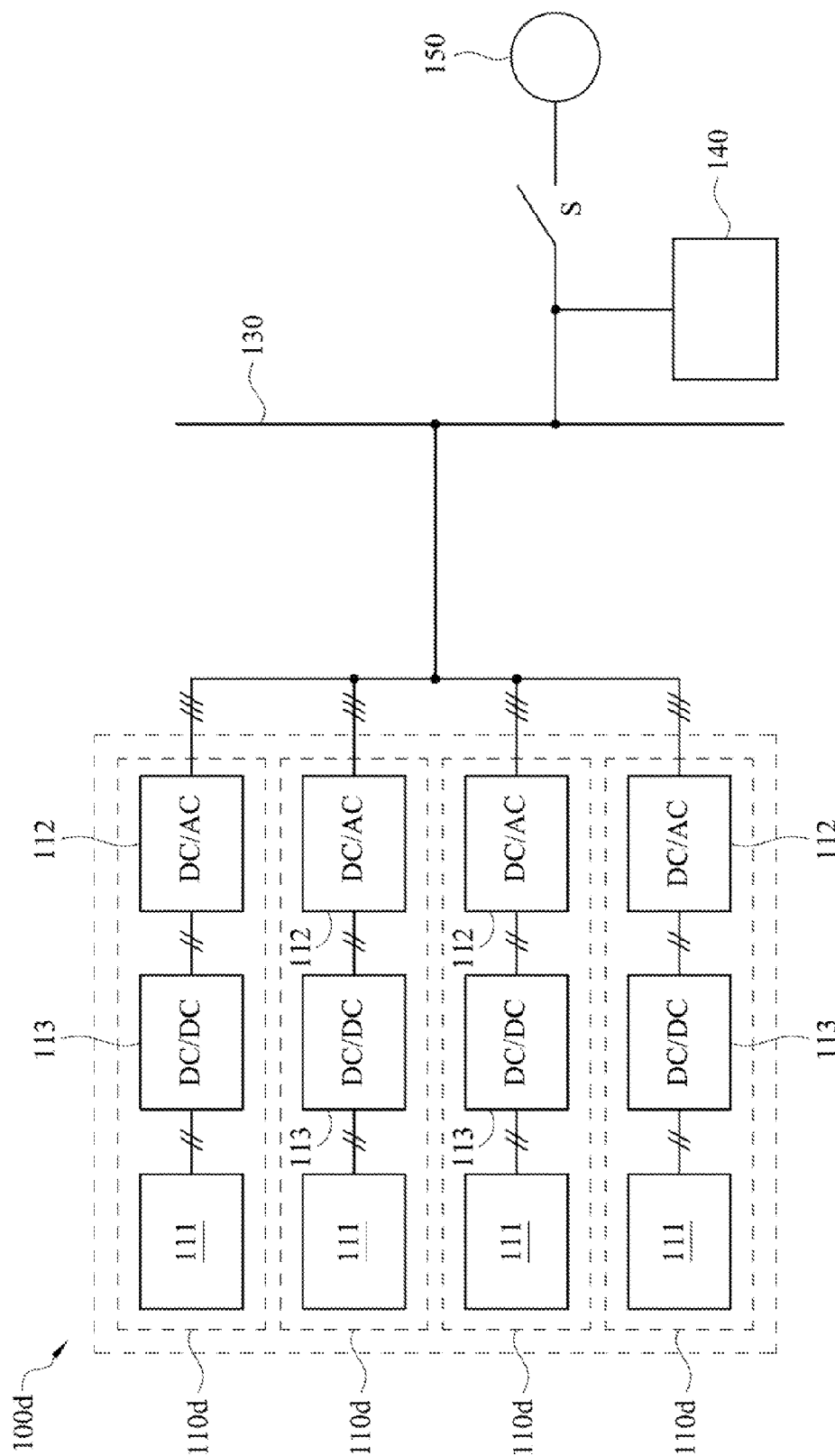


Fig. 1d  
(Prior Art)

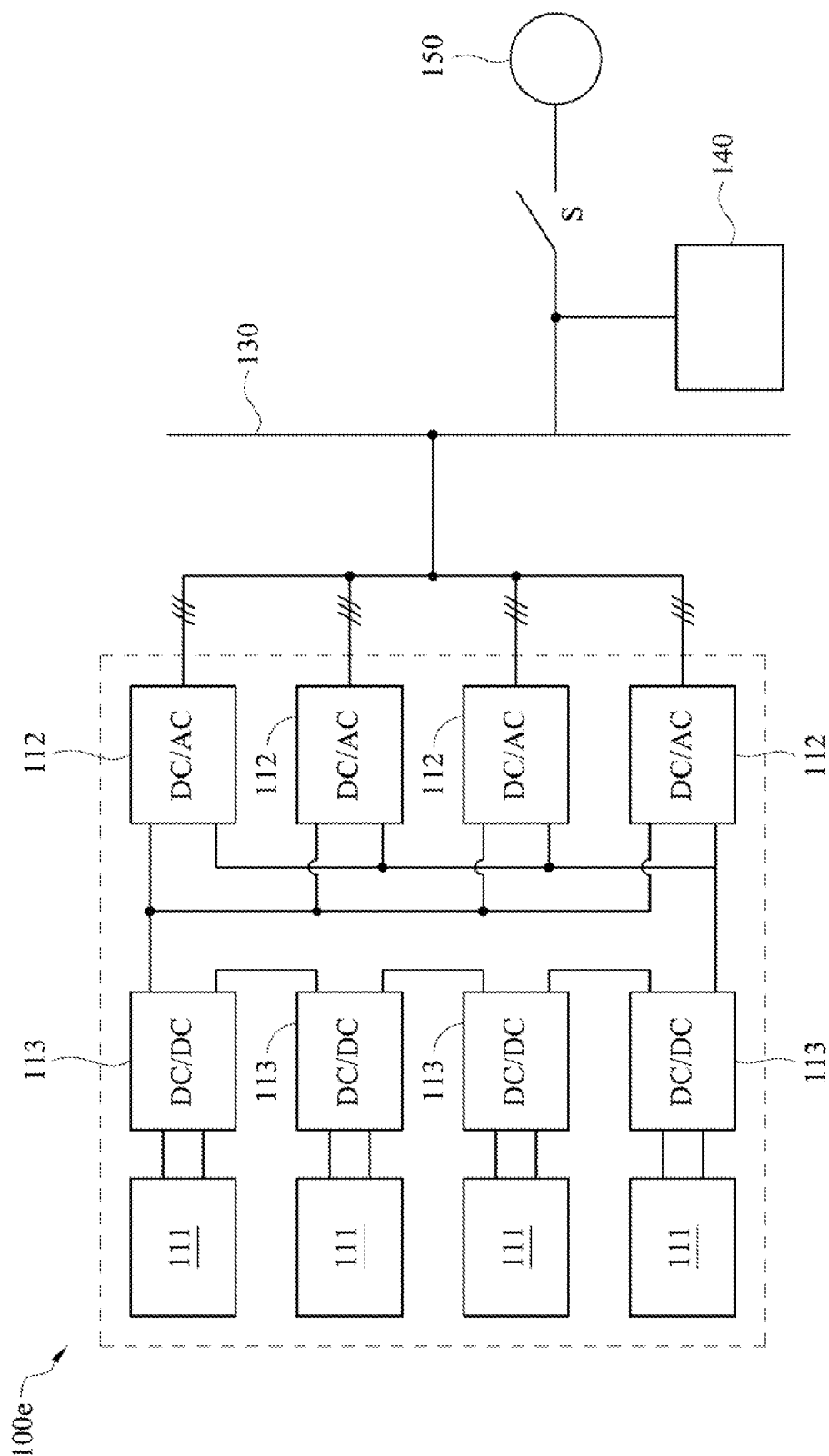
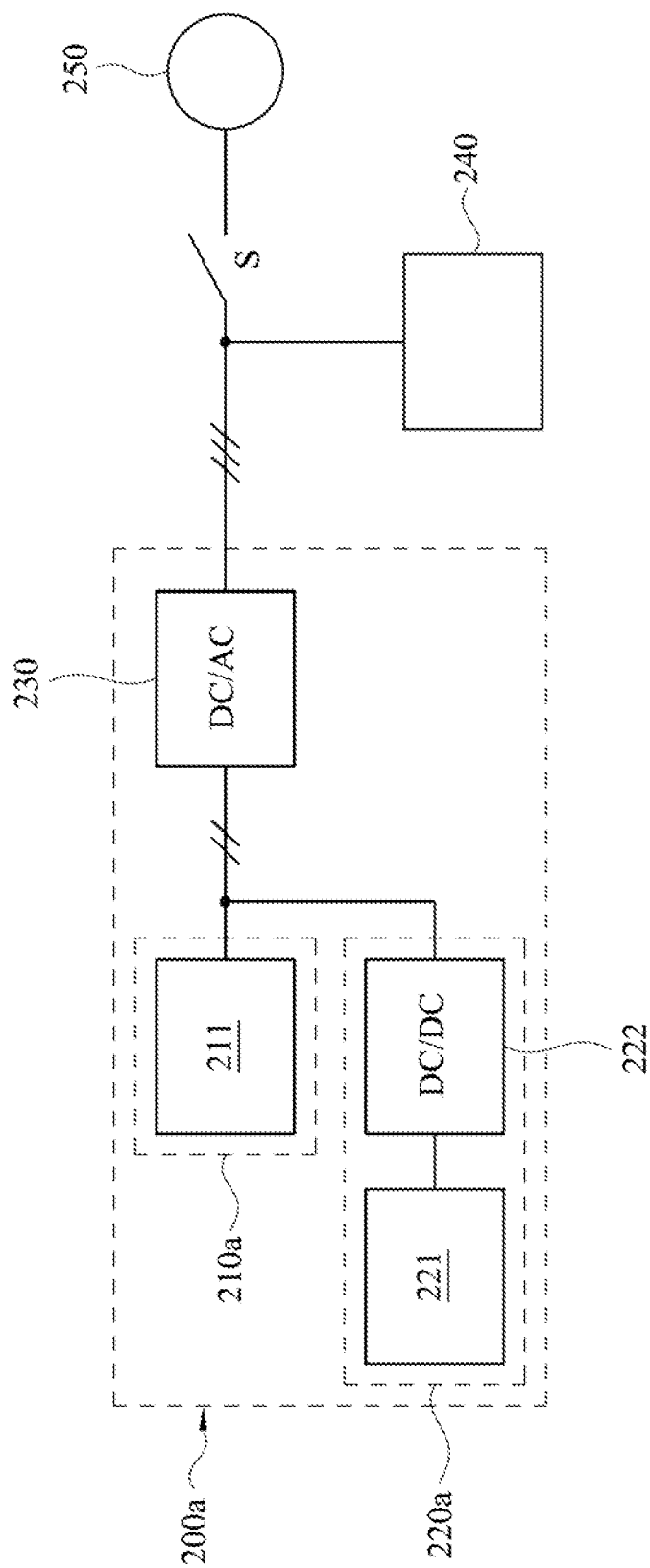


Fig. 1e  
(Prior Art)



2  
50  
- 1000  
[11]



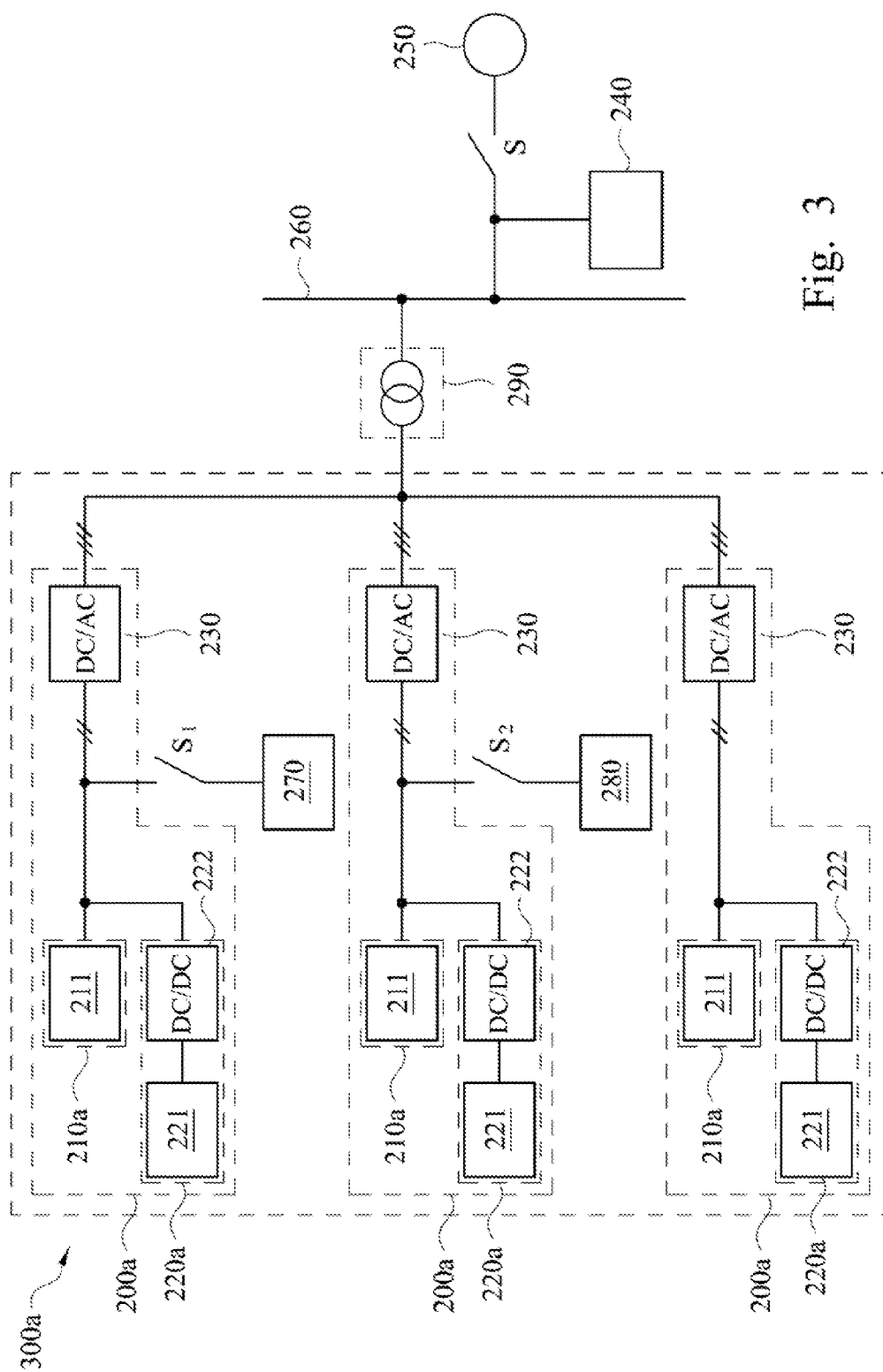


Fig. 3

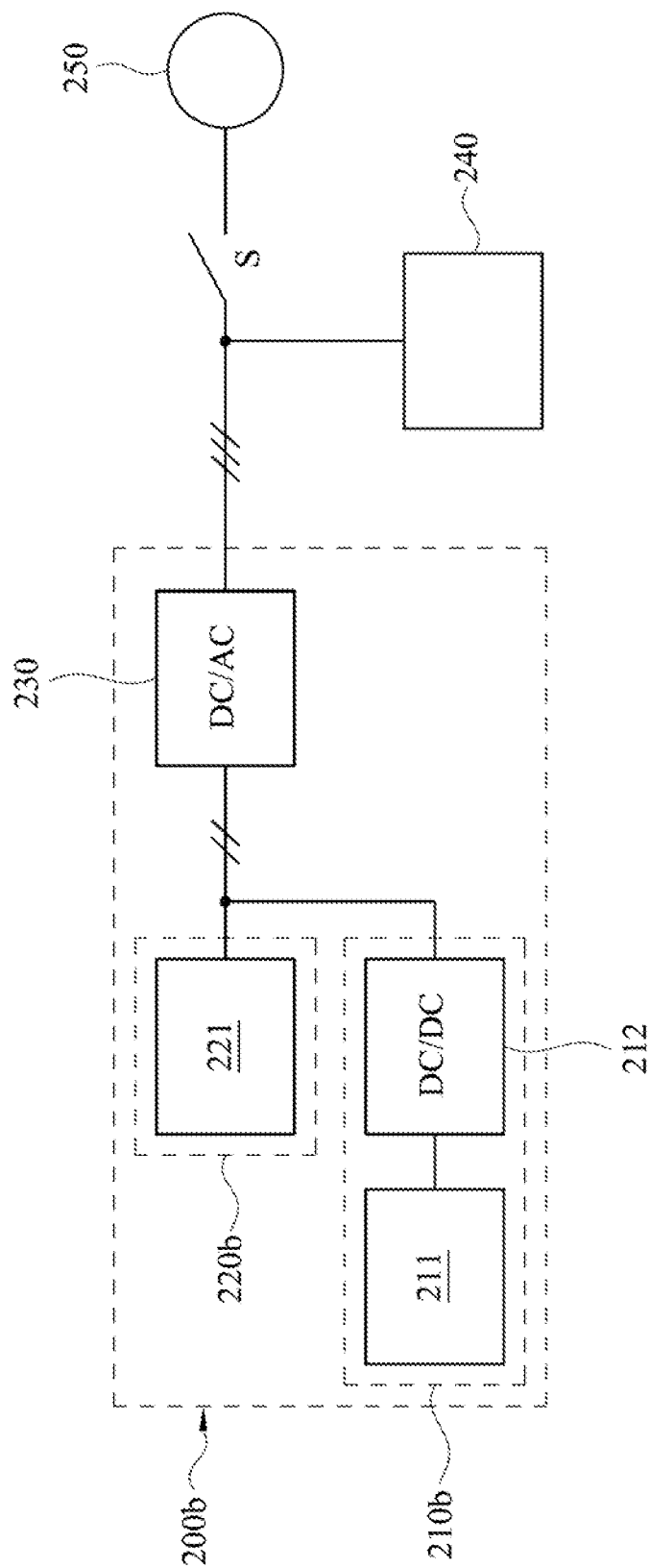


Fig. 4

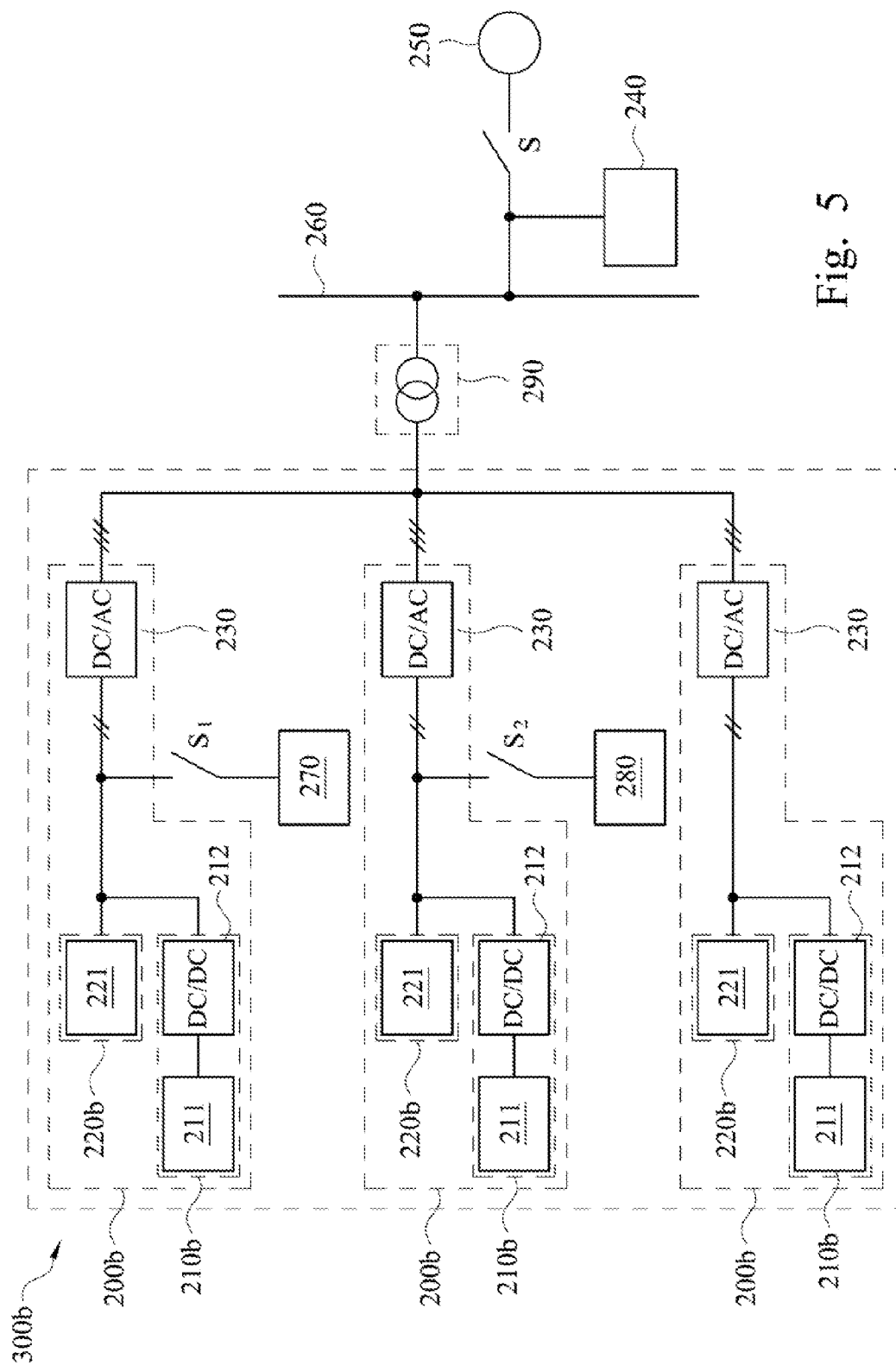


Fig. 5

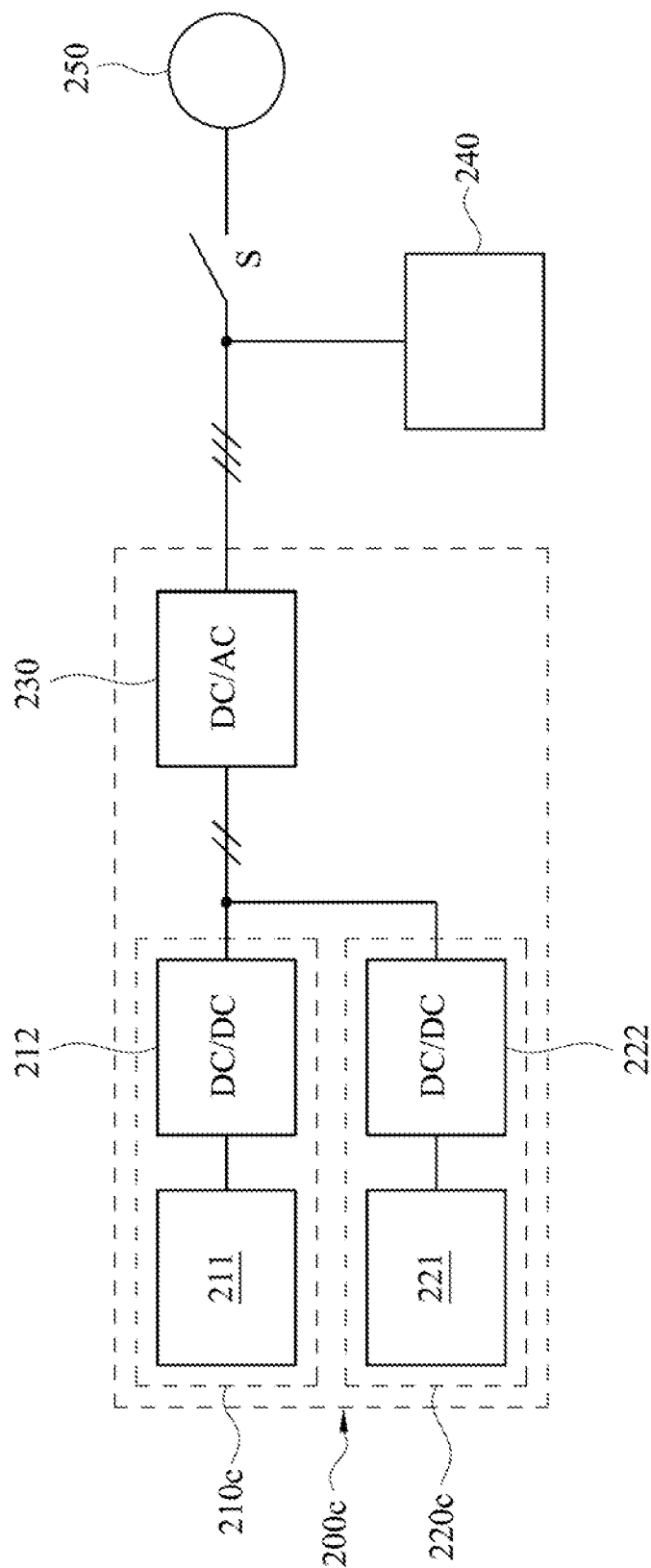


Fig. 6

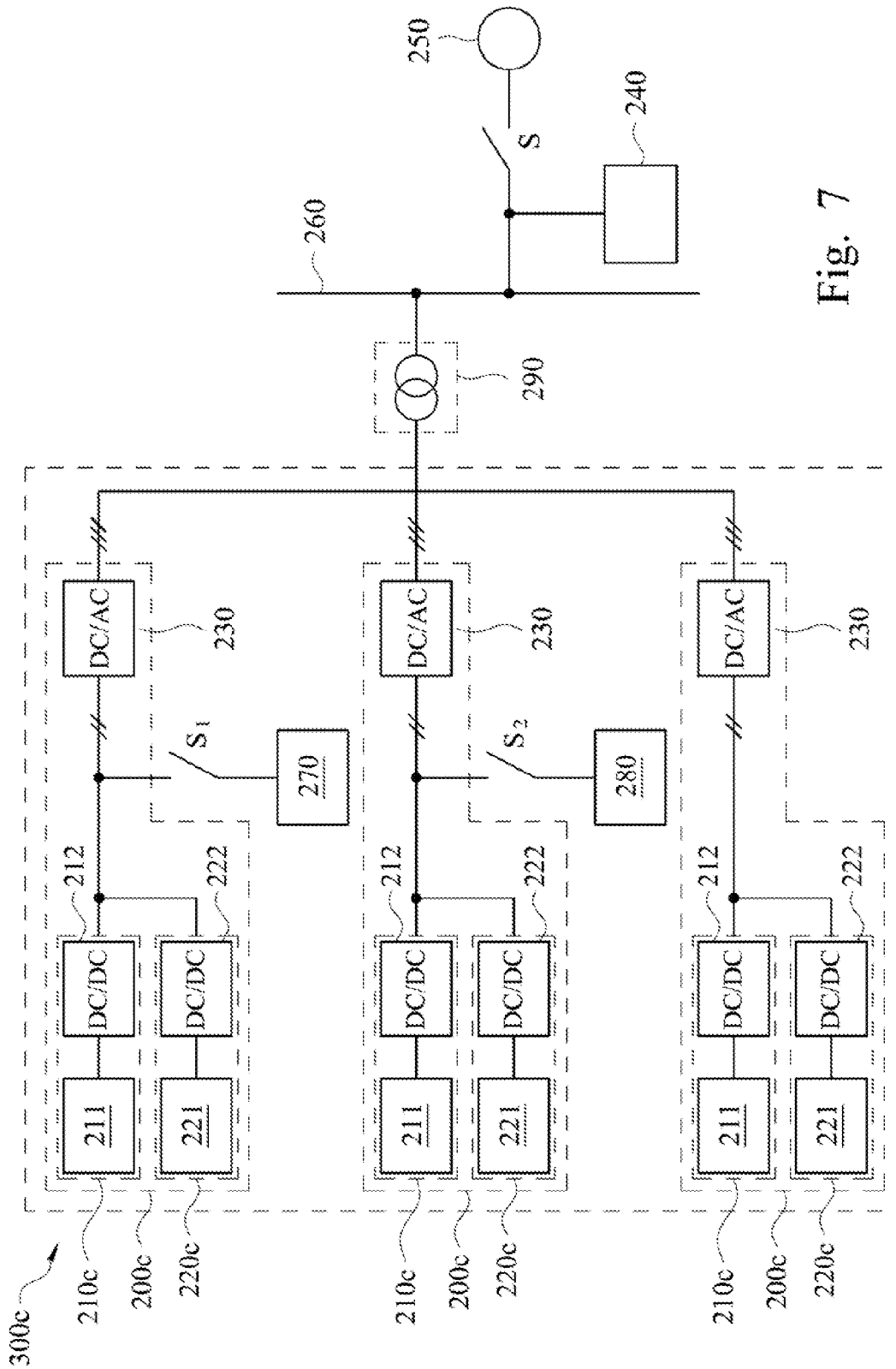


Fig. 7

1

# POWER STORAGE MODULE AND POWER STORAGE DEVICE

## RELATED APPLICATIONS

This application claims priority to China Application Serial Number 201310409995.2, filed Sep. 10, 2013, which is herein incorporated by reference.

## BACKGROUND

### 1. Field of Invention

The present invention relates to a power storage module. More particularly, the present invention relates to a power storage module and a power storage device with a power management function.

### 2. Description of Related Art

With advances in science and technology, there has been an increase in the demand for high power quality. In order to provide an AC sinusoidal wave with a stable voltage, a stable frequency, no electrical surge, no peak disturbance, and no harmonic wave, a power storage device is utilized to suppress mains voltage fluctuations, frequency shifting, harmonic waves, and unbalanced three-phase voltage. The power storage device also provides emergency protection measures when electricity supply failure is encountered or electrical surge occurs unexpectedly. Moreover, with respect to renewable energy, because most power generated by a renewable energy generating apparatus may change a periodically and unexpectedly, when, for example, solar power, wind power, or tidal power is inputted directly into a power grid, this may seriously affect the operation stability of the power grid, thereby limiting the development and utilization of renewable energy. By setting up a power storage device between the renewable energy generating apparatus and the power grid, the power may be buffered and regulated such that the utilization of renewable energy may be increased.

According to power storage technology, traditional power storage devices with a large capacity may be classified into five types. Reference is made to FIG. 1*a*. FIG. 1*a* illustrates a conventional single-stage isolation power storage device 100*a*. The power storage device 100*a* includes plural power storage modules 110*a*, and each of the power storage modules 110*a* includes a storage cell 111 and a DC/AC converter 112. The storage cell 111 is coupled to the DC side of the DC/AC converter 112. In addition, the AC side of each of the DC/AC converters 112 is coupled to one side of a transformer 120 in parallel to isolate the power storage modules 110*a*. The other side of the transformer 120 is coupled to an AC bus 130. The power storage device 100*a* collects the power to the AC bus 130 through the transformer 120. The power storage device 100*a* connects an AC load 140 independently by the AC bus 130 or connects an AC power grid 150 inline by a switch S.

FIG. 1*b* illustrates a conventional single-stage non-isolation power storage device 100*b*. Similar to the power storage device 100*a*, each of a plurality of power storage modules 110*b* of the power storage device 100*b* includes a storage cell 111 and a DC/AC converter 112. Each of the power storage modules 110*b* is coupled to an AC bus 130 in parallel directly. Reference is made to FIG. 1*c*. FIG. 1*c* illustrates a conventional double-stage isolation power storage device 100*c*. Each of a plurality of power storage modules 110*c* of the power storage device 100*c* includes a storage cell 111, a DC/AC converter 112 and a DC/DC converter 113. The storage cell 111 is connected to the DC side of the DC/AC converter 112 through the DC/DC converter 113. Similarly, the AC side of each of the DC/AC converters 112 is coupled

2

to one side of a transformer 120 in parallel. The other side of the transformer 120 is coupled to an AC bus 130. The power storage device 100*c* collects the power to the AC bus 130 through the voltage transformer 120. The power storage device 100*a* connects an AC load 140 independently by the AC bus 130 or connects an AC power grid 150 inline by a switch S.

Furthermore, FIG. 1*d* illustrates a conventional double-stage non-isolation power storage device 100*d*. Similar to the power storage device 100*c*, in each of a plurality of power storage modules 110*d* of the power storage device 100*d*, a storage cell 111 is connected to the DC side of a DC/AC converter 112 through a DC/DC converter 113. Each of the power storage modules 110*d* is coupled to an AC bus 130 in parallel directly.

Moreover, there is a power storage technology with a more complicated control method. Reference is made to FIG. 1*e*. FIG. 1*e* illustrates a conventional double-stage serial power storage device 100*e*. As shown in FIG. 1*e*, in the power storage device 100*e*, each output of a plurality of DC/DC converters 113 is connected to each other in series. Each DC side of a plurality of DC/AC converters 112 is connected to each other in parallel. Each of a plurality of storage cells 111 collects the power to an AC bus 130 through the serially connected DC/DC converters 113 and the parallel-connected DC/AC converters 112, connects an AC load 140 independently through the AC bus 130, or connects an AC power grid 150 inline through a switch S.

All of the power storage devices above utilize the storage cells as storage elements. However, the characteristics of conventional storage cells are, for example, low power density, and long charging time, that is, slow response for dynamic load compensation. To be more precise, if the DC/AC converter is a three-phase converter, when the three-phase load is unbalanced, a ripple current with a low frequency of the DC bus which is coupled to the DC side of the DC/AC converter is large. Moreover, a ripple current with a low frequency is distributed between the storage cell and the capacitor of the DC bus and the amount of the distributed current is dependent upon the output impedance. A ripple current with a low frequency may not only increase the heat loss of the storage cell so that the life of the storage cell is affected, but also may result in a wide undulating voltage of the DC bus such that the quality of the current wave is affected and the stability of the power system is decreased. Furthermore, a deep discharge has a significant impact on the storage cell. Normally, the number of charge/discharge cycles of a storage cell seldom exceeds one thousand. Therefore, the maintenance cost of the power storage device with storage cells is increased.

For the foregoing reasons, there is a need for configuring a power storage module more efficiently so that the efficiency of the power storage device and the stability of the power system may be improved.

## SUMMARY

To solve the issues above, this invention provides a power storage module including a power storage unit and a power management unit. The power storage unit includes a storage cell configured to provide a steady state power to the system. The power management unit includes a super capacitor configured to buffer the power of the system. When the three-phase load is unbalanced, the power management unit may restrain the undulating voltage of the AC power grid rapidly by the super capacitor. The super capacitor may absorb the ripple current with a low frequency generated by the DC side

3

of the DC/AC converter effectively, such that the ripple current with a low frequency is prevented from increasing the heat loss of the storage cell. Accordingly, the quality of the output current wave is improved, the voltage stress is decreased and the stability of the power system is improved. Moreover, the efficiency of the power storage device with the power storage module above is improved and costs associated with disposing additional storage cells are avoided.

One aspect of the present disclosure is to provide a power storage module including a DC/AC converter, a first power storage element, a second power storage element and at least one DC/DC converter. The first power storage element is coupled to the DC side of the DC/AC converter to form a first power storage branch. The second power storage element is coupled to the DC side of the DC/AC converter to form a second power storage branch. The first power storage branch and the second power storage branch are connected in parallel. The DC/DC converter is disposed on the first power storage branch or the second power storage branch.

Another aspect of the present disclosure is to provide a power storage device including plurality of the power storage modules above-mentioned, wherein the AC sides of the DC/AC converters in the power storage modules are connected to each other in parallel.

Another aspect of the present disclosure is to provide a power storage module including a DC/AC converter, an AC load, a power storage unit and a power management unit. The AC load is coupled to the AC side of the DC/AC converter. The power storage unit and the power management unit are coupled to the DC side of the DC/AC converter. When the AC load is in a steady state, the power storage unit is configured to provide a steady state power to the AC load. When a change in the AC load occurs, the power management unit is configured to buffer the AC load through the DC/AC converter. The power storage unit and the power management unit are connected in parallel.

It is to be understood that both the foregoing general description and the following detailed description are by examples, and are intended to provide further explanation of the invention as claimed.

### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. In the drawings,

FIG. 1a illustrates a conventional single-stage isolation power storage device;

FIG. 1b illustrates a conventional single-stage non-isolation power storage device;

FIG. 1c illustrates a conventional double-stage isolation power storage device;

FIG. 1d illustrates a conventional double-stage non-isolation power storage device;

FIG. 1e illustrates a conventional double-stage serial power storage device;

FIG. 2 is a schematic diagram illustrating a power storage module according to one embodiment of the present invention;

FIG. 3 is a schematic diagram illustrating a power storage device according to one embodiment of the present invention;

FIG. 4 is a schematic diagram illustrating a power storage module according to another embodiment of the present invention;

4

FIG. 5 is a schematic diagram illustrating a power storage device according to another embodiment of the present invention;

FIG. 6 is a schematic diagram illustrating a power storage module according to another embodiment of the present invention; and

FIG. 7 is a schematic diagram illustrating a power storage device according to another embodiment of the present invention.

### DESCRIPTION OF THE EMBODIMENTS

Reference will now be made in detail to the present embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

Reference is made to FIG. 2. FIG. 2 is a schematic diagram illustrating a power storage module according to one embodiment of the present invention. As shown in FIG. 2, the power storage module 200a includes a power storage unit 210a, a power management unit 220a and a DC/AC converter 230. The power storage unit 210a and the power management unit 220a are both coupled to the DC side of the DC/AC converter 230. The power storage unit 210a and the power management unit 220a are connected in parallel.

The AC side of the DC/AC converter 230 is coupled to an AC load 240 and coupled to an AC power grid 250 through a switch S. By turning off or turning on the switch S, the DC/AC converter 230 connects the AC load 240 independently, or connects the AC load 240 and the AC power grid 250 in parallel. When the AC load 240 is in a steady state, the power storage unit 210a of the power storage module 200a provides a sufficient steady state power to the AC load 240 through the DC/AC converter 230. In other words, it provides a steady power to the user side. When a change in the AC load occurs (that is, a discontinuous load condition is encountered, in which discontinuous load refers to a step change), the power management unit 220a of the power storage module 200a may buffer the AC load 240 through the DC/AC converter 230. In other words, voltage fluctuations and frequency shifting resulting from a discontinuous AC load 240 may be restrained.

In this embodiment, the power storage unit 210a may include a first power storage element 211, and the power management unit 220a may include a second power storage element 221 and a DC/DC converter 222. The second power storage element 221 is connected to the power storage unit 210a in parallel through the DC/DC converter 222, that is, connected to the first power storage element 211 in parallel.

Further, the first power storage element 211 in the power storage unit 210a which provides a steady state power is different from the second power storage element 221 in the power management unit 220a which buffers power. The power storage unit 210a is utilized to provide power continuously, so the capacity of the first power storage element 211 needs to be large. The power management unit 220a is utilized to buffer power rapidly, so the charging/discharging speed of the second power storage element 221 needs to be fast. Accordingly, the capacity of the first power storage element 211 is typically larger than that of the second power storage element 221.

In the present embodiment, the first power storage element 211 may be a storage cell, for example, a lead-acid cell, a nickel-cadmium cell, a nickel metal hydride battery, a sodium-sulfur cell, a lithium cell or a fuel cell. The kind of the storage cell is not limited to those mentioned in the present

5

embodiment. Further, the second power storage element **221** may be a super capacitor. Compared to a storage cell, a super capacitor possesses the characteristics of high power density, high charging/discharging speed, low energy density, and a high number of charge/discharge cycles (possibly more than ten thousand). Because of the high charging/discharging speed of a super capacitor, when a change in the AC load **240** occurs, voltage fluctuations due to the AC load **240** may be restrained by the super capacitor rapidly, and the power may be buffered too. When the AC load **240** is in a steady state, a storage cell with a high energy density may provide steady power to the AC load **240**. Therefore, the efficiency of the power storage module is optimized.

Moreover, the first power storage element **211** (e.g., storage cell) of the power storage unit **210a** is coupled to the DC side of the DC/AC converter **230** to form a first power storage branch. The second power storage element **221** (e.g., super capacitor) of the power management unit **220a** is coupled to the DC side of the DC/AC converter **230** to form a second power storage branch through the DC/DC converter **222**. Each of the first power storage branch and the second power storage branch is a single circuit. Accordingly, control of the storage cell and the super capacitor is easy, and problems associated with balancing of the lifespan of the storage cells are not encountered.

In the present embodiment, the second power storage element **221** (e.g., super capacitor) of the power management unit **220a** is connected to the first power storage element **211** (e.g., storage cell) in parallel. That is, the DC/DC converter **222** is disposed on the second power storage branch. Because the voltage of a single super capacitor is from about 2V to about 3V and the DC side voltage of the DC/AC converter **230** is higher than this level, the voltage of the super capacitor may be boosted through the DC/DC converter **222** in order to make the power management unit **220a** provide sufficient voltage to the DC side of the DC/AC converter **230**. Accordingly, the required number of the super capacitors in series is reduced. When the load power changes, the power management unit **220a** may provide buffering energy rapidly so that the load impact is restrained because the super capacitor is discharged fast.

Further, if the DC/AC converter **230** is a three-phase converter, that is, the power storage module **200a** is installed in a three-phase power system and the AC load **240** is a three-phase load, when the AC load **240** is unbalanced, a higher ripple current with a low frequency may be generated on the DC side of the DC/AC converter **230**. The ripple current with a low frequency may be absorbed efficiently by the second power storage element **221** (e.g., super capacitor) of the power management unit **220a**. Moreover, the output impedance of the super capacitor on the second power storage branch may be reduced through the DC/DC converter **222**, such that the effect from the larger equivalent series resistance (ESR) of the super capacitor may be avoided. As a result, not only is an increase in heat loss of the power cell due to a ripple current with a low frequency prevented, but a reduction in the lifespan of the power cell is also prevented. Thus, the stability of the power system may be improved. In some embodiments, the DC side of the DC/AC converter **230** in the power storage module **200a** may be coupled to a DC load so that the power storage module **200a** may provide power to the DC load independently. In some embodiments, the DC side of the DC/AC converter **230** in the power storage module **200a** may be coupled to at least one power input module. In other words, the first power storage element **211** (e.g., storage cell) and the second power storage element **221** (e.g., super capacitor) of the power storage module **200a** may be energized by the

6

power input module. The power input module may be a renewable energy generating apparatus, for example, a solar energy generating apparatus, a wind power generating apparatus, a tidal power generating apparatus, and so on.

Reference is made to FIG. 3. FIG. 3 is a schematic diagram illustrating a power storage device according to one embodiment of the present invention. As shown in FIG. 3, the power storage device **300a** includes a plurality of the power storage modules **200a** of FIG. 2. The AC side of the DC/AC converter **230** in each power storage module **200a** is connected to each other in parallel. In the present embodiment, the quantity of the power storage modules **200a** is three, but the present embodiment is not limited to any quantity. In practice, the power storage device **300a** may be an isolation type or a non-isolation type power storage device. That is, the power storage device **300a** may be coupled to an AC bus **260** directly or through a transformer **290**. In the present embodiment, the power storage device **300a** is an isolation type power storage device, but the present embodiment is not limited to any type of power storage device. The DC/AC converter **230** of at least one power storage module **200a** may be a three-phase converter in the power storage device **300a**. In the power storage device **300a**, the AC side of each DC/AC converter **230** is coupled to one side of the transformer **290**. The other side of transformer **290** is coupled to the AC bus **260**. The power storage device **300a** collects the power to the AC bus **260** through the transformer **290**. The power storage device **300a** connects an AC load **240** independently by the AC bus **260** or connects an AC power grid **250** inline by a switch S.

Moreover, in the power storage device **300a**, the DC side of the DC/AC converter **230** of at least one power storage module **200a** is coupled to a DC load **270** through a switch S1 so that the power storage module **200a** may provide power to the DC load **270** independently. Furthermore, in the power storage device **300a**, the DC side of the DC/AC converter **230** of at least one power storage module **200a** is coupled to at least one power input module **280** through a switch S2. In other words, the first power storage element **211** (e.g., storage cell) and the second power storage element **221** (e.g., super capacitor) of the power storage module **200a** may be energized by the power input module **280**. The power input module **280** may be a renewable energy generating apparatus, for example, a solar power generating apparatus, a wind power generating apparatus, a tidal power generating apparatus, and so on. Because a super capacitor may restrain voltage fluctuations rapidly, a power buffering effect may be achieved. Therefore, by installing the power storage module **200a** between the power input module **280** and the AC power grid **250**, the utilization efficiency of renewable energy may be improved.

Accordingly, a greater power demand of the power system may be realized by a power storage device with multiple power storage modules. Because each power storage branch is a single circuit in the power storage module, any quantity of the power storage modules can be added easily and flexibly. Moreover, in every power storage module, a DC load or a power input module is configured on the DC side of the DC/AC converter, such that the utilization efficiency of the power storage device is improved.

Reference is made to FIG. 4. FIG. 4 is a schematic diagram illustrating a power storage module according to another embodiment of the present invention. Similarly, the power storage module **200b** includes a power storage unit **210b**, a power management unit **220b** and a DC/AC converter **230**. The power storage unit **210b** and the power management unit **220b** are both coupled to the DC side of a DC/AC converter **230**. The power storage unit **210b** may include a first power



7

storage element **211** and a DC/DC converter **212**, and the power management unit **220b** may include a second power storage element **221**. The first power storage element **211** is connected to the power management unit **220b** in parallel through the DC/DC converter **212**, that is, connected to the second power storage element **221** in parallel. The first power storage element **211** may be a storage cell, for example, a lead-acid cell, a nickel-cadmium cell, a nickel metal hydride battery, a sodium-sulfur cell, a lithium cell or a fuel cell. The kind of the storage cell is not limited to those mentioned in the present embodiment. Further, the second power storage element **221** may be a super capacitor. The capacity of the first power storage element **211** is larger than that of the second power storage element **221**.

Similarly, the first power storage element **211** (e.g., storage cell) of the power storage unit **210b** is coupled to the DC side of the DC/AC converter **230** to form a first power storage branch through the DC/DC converter **212**. That is, the DC/DC converter **212** is disposed on the first power storage branch. The second power storage element **221** (e.g., super capacitor) of the power management unit **220b** is coupled to the DC side of the DC/AC converter **230** to form a second power storage branch. Each of the first power storage branch and the second power storage branch is a single circuit. It should be noted that if the DC/AC converter **230** is a three-phase converter, and the AC load **240** is a three-phase load, when the AC load **240** is unbalanced, a higher ripple current with a low frequency may be generated on the DC side of the DC/AC converter **230**. The first power storage element **211** (e.g., storage cell) of the power storage unit **210b** may increase the impedance of the first power storage branch through the DC/DC converter **212** so that the ripple current with a low frequency may be mainly absorbed by the second power storage element **221** (e.g., super capacitor) of the second power storage branch. The connection and operation of the power storage module **200b** are the same as those of the power storage module **200a**, and so a description in this regard is not repeated herein.

Reference is made to FIG. 5. FIG. 5 is a schematic diagram illustrating a power storage device according to another embodiment of the present invention. Similarly, the power storage device **300b** includes a plurality of the power storage modules **200b** of FIG. 4. The connection and the operation of the power storage modules **200b** are described in relation to FIG. 4, and are not repeated herein. Moreover, comparing FIG. 5 with FIG. 3, the major difference therebetween is that, in FIG. 5, the power storage unit **210b** of each of the power storage modules **200b** includes the first power storage element **211** and the DC/DC converter **212** connected in series, while in FIG. 3, the power storage unit **210a** of each of the power storage modules **200a** only includes the second power storage element **221**. Further, in FIG. 5, the power management unit **220b** of each of the power storage modules **200b** merely includes the second power storage element **221**, while in FIG. 3, the power management unit **220a** of each of the power storage modules **200a** includes the second power storage element **221** and the DC/DC converter **222** connected in series. In other words, in FIG. 3, the DC/AC converter of the power storage module **200a** is configured on the second power storage branch, while in FIG. 5, the DC/AC converter **230** of each of the power storage modules **200b** is configured on the first power storage branch. It should be noted that the power storage device **300b** may be an isolation type or a non-isolation type power storage device. In the present embodiment, the power storage device **300b** is an isolation type power storage device, but the present embodiment is not limited to any type of the power storage device.

8

Reference is made to FIG. 6. FIG. 6 is a schematic diagram illustrating a power storage module according to another embodiment of the present invention. Similarly, the power storage module **200c** includes a power storage unit **210c**, a power management unit **220c** and a DC/AC converter **230**. The power storage unit **210c** and the power management unit **220c** are both coupled to the DC side of the DC/AC converter **230**. The power storage unit **210c** and the power management unit **220c** are connected in parallel. The power storage unit **210c** may include a first power storage element **211** and a DC/DC converter **212**, and the power management unit **220c** may include a second power storage element **221** and a DC/DC converter **222**. The first power storage element **211** is coupled to the DC side of the DC/AC converter **230** through the DC/DC converter **212**. The second power storage element **221** coupled to the DC side of the DC/AC converter **230** through the DC/DC converter **222**.

Similarly, the first power storage element **211** may be a storage cell, for example, a lead-acid cell, a nickel-cadmium cell, a nickel metal hydride battery, a sodium-sulfur cell, a lithium cell or a fuel cell. The kind of the storage cell is not limited to those mentioned in the present embodiment. Further, the second power storage element **221** may be a super capacitor. The capacity of the first power storage element **211** is larger than that of the second power storage element **221**.

Similarly, the first power storage element **211** (e.g., storage cell) of the power storage unit **210c** is coupled to the DC side of the DC/AC converter **230** to form a first power storage branch through the DC/DC converter **212**. That is, the DC/DC converter **212** is disposed on the first power storage branch. Moreover, the second power storage element **221** (e.g., super capacitor) of the power management unit **220c** is coupled to the DC side of the DC/AC converter **230** to form a second power storage branch through the DC/DC converter **222**. That is, the DC/DC converter **222** is disposed on the second power storage branch. Each of the first power storage branch and the second power storage branch is a single circuit respectively.

In the present embodiment, the power storage module **200c** combines the advantages of the power storage module **200a** in FIG. 3 and the power storage module **200b** in FIG. 5. Accordingly, if the DC/AC converter **230** is a three-phase converter, and the AC load **240** is a three-phase load, when the AC load **240** is unbalanced, a higher ripple current with a low frequency may be generated on the DC side of the DC/AC converter **230**. The first power storage element **211** (e.g., storage cell) of the power storage unit **210c** may increase the impedance of the first power storage branch through the DC/DC converter **212** so that the ripple current with a low frequency may be mainly absorbed by the second power storage element **221** (e.g., super capacitor) of the second power storage branch. Moreover, the second power storage element **221** (e.g., super capacitor) of the power management unit **220c** may decrease the output impedance of the second power storage branch through the DC/DC converter **222**. The effect from the larger equivalent series resistance (ESR) of the super capacitor may be avoided. The super capacitor may absorb the ripple current with a low frequency and the voltage thereof may be boosted through the DC/DC converter **222** so that the required quantity of the super capacitors in series reduced. Accordingly, not only is an increase in heat loss owing of the storage cell due to a ripple current with a low frequency prevented, but a reduction in the life span of the storage cell is also prevented. Hence, the stability of the power system is improved.

Reference is made to FIG. 7. FIG. 7 is a schematic diagram illustrating a power storage device according to another embodiment of the present invention. Similarly, the power

storage device 300c includes a plurality of the power storage modules 200c of FIG. 6. The connection and operation of the power storage module 200c are described in related description for FIG. 6, and are not repeated herein. It should be noted that the power storage device 300c may be an isolation type or a non-isolation type power storage device. In the present embodiment, the power storage device 300c is an isolation type power storage device, but the present embodiment is not limited to any type of power storage device.

Accordingly, a greater power demand of the power system may be realized by the power storage device with multiple power storage modules. Because each power storage branch is a single circuit in the power storage module, any quantity of the power storage modules can be added easily and flexibly. Moreover, in every power storage module, a DC load or a power input module is configured on the DC side of the DC/AC converter, such that the utilization efficiency of the power storage device is improved.

According to the embodiments of the present invention above, the power storage unit and the power management unit are configured in the power storage module. The power storage unit includes a storage cell providing a steady state power to the system. The power management unit includes a super capacitor buffering the power of the system. When the three-phase load is unbalanced, the power management unit may restrain the undulating voltage of the AC power grid rapidly by the super capacitor. The super capacitor may absorb the ripple current with a low frequency generated by the DC side of the DC/AC converter effectively, prevent the ripple current with a low frequency from increasing the heat loss of the storage cell, improve the quality of the output current wave, decrease the voltage stress of the power device, and improve the stability of the power system. Moreover, the super capacitor may be charge/discharged more than ten thousand times so that the cycle life of the storage cell is increased. The utilization efficiency of the power storage device and the power storage module is improved, and costs associated with having to dispose additional storage cells are avoided.

Although the present invention has been described in considerable detail with reference to certain embodiments thereof, other embodiments are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the embodiments contained herein.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of the present invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A power storage module, comprising:  
a DC/AC converter,  
a first power storage element;  
a second power storage element; and  
at least one DC/DC converter,

wherein the first power storage element and the second power storage element are coupled to the DC side of the DC/AC converter to form a first power storage branch and a second power storage branch respectively, wherein the first power storage branch and the second power storage branch are connected in parallel, and wherein the at least one DC/DC converter is disposed on the first power storage branch to increase an output impedance of the first power storage branch or disposed on the second power storage branch to decrease an output impedance of the second power storage branch,

wherein a capacity of the first power storage element is greater than a capacity of the second power storage element, the first power storage element is a storage cell, and the second power storage element is a super capacitor.

2. The power storage module of claim 1, wherein the storage cell includes a lead-acid cell, a nickel-cadmium cell, a nickel metal hydride battery, a sodium-sulfur cell, a lithium cell or a fuel cell.

3. The power storage module of claim 1, wherein the at least one DC/DC converter is disposed on the first power storage branch and the first power storage element is coupled to the DC side of the DC/AC converter through the at least one DC/DC converter.

4. The power storage module of claim 1, wherein the at least one DC/DC converter is disposed on the second power storage branch and the second power storage element is coupled to the DC side of the DC/AC converter through the at least one DC/DC converter.

5. The power storage module of claim 1, wherein the at least one DC/DC converter include a first DC/DC converter and a second DC/DC converter, wherein the first DC/DC converter and the second DC/DC converter are disposed on the first power storage branch and the second power storage branch respectively, wherein the first power storage element is coupled to the DC side of the DC/AC converter through the first DC/DC converter and wherein the second power storage element is coupled to the DC side of the DC/AC converter through the second DC/DC converter.

6. The power storage module of claim 1, wherein the DC/AC converter is a three-phase converter.

7. The power storage module of claim 1, wherein the AC side of the DC/AC converter is coupled to an AC power grid.

8. The power storage module of claim 1, wherein the AC side of the DC/AC converter is coupled to an AC load.

9. The power storage module of claim 1, wherein the DC side of the DC/AC converter is coupled to a DC load.

10. The power storage module of claim 1, wherein the DC side of the DC/AC converter is coupled to at least one power input module.

11. A power storage device, comprising a plurality of the power storage modules of claim 1, wherein the AC sides of the DC/AC converters in the power storage modules are connected to each other in parallel.

12. The power storage device of claim 11, wherein the DC/AC converter in at least one of the power storage modules is a three-phase converter.

13. The power storage device of claim 11, wherein the DC side of the DC/AC converter in at least one of the power storage modules is coupled to a DC load.

14. The power storage device of claim 11, wherein the DC side of the DC/AC converter in at least one of the power storage modules is coupled to at least one power input module.

15. The power storage device of claim 14, wherein the at least one power input module includes a solar energy generation input module, a wind power generation input module, or a tidal power generation input module.

16. The power storage device of claim 11, wherein the AC side of the DC/AC converter in each of the power storage modules is coupled to an AC bus through a transformer.

17. The power storage device of claim 16, wherein the AC bus is electrically coupled to an AC power grid or an AC load.

18. The power storage device of claim 11, wherein the AC side of the DC/AC converter in each of the power storage modules is electrically coupled to an AC bus directly.

## 11

19. The power storage device of claim 18, wherein the AC bus is electrically coupled to an AC power grid or an AC load.

20. A power storage module, comprising:

a DC/AC converter;

an AC load coupled to the AC side of the DC/AC converter; 5

a power storage unit coupled to the DC side of the DC/AC converter, wherein when the AC load is in a steady state, the power storage unit is configured to provide a steady state power to the AC load; and

a power management unit coupled to the DC side of the DC/AC converter, wherein when a change in the AC load occurs, the power management unit is configured to buffer the AC load through the DC/AC converter; 10

wherein the power storage unit and the power management unit are connected in parallel,

wherein the power storage unit includes a first power storage element, the power management unit includes a second power storage element, and a capacity of the first power storage element is larger than a capacity of the second power storage element, 15

wherein

the power storage unit further includes a first DC/DC converter, the first power storage element is coupled to the DC side of the DC/AC converter through the first DC/DC converter to form a first power storage branch, and the first DC/DC converter is configured to increase an output impedance of the first power storage branch; or

the power management unit includes a second DC/DC converter, the second power storage element is 20

## 12

coupled to the DC side of the DC/AC converter through the second DC/DC converter to form a second power storage branch, and the second DC/DC converter is configured to decrease an output impedance of the second power storage branch.

21. The power storage module of claim 20, wherein the power storage unit further includes the first DC/DC converter, and the power management unit further includes the second DC/DC converter, wherein the first power storage element is coupled to the DC side of the DC/AC converter through the first DC/DC converter to form the first power storage branch, and wherein the second power storage element is coupled to the DC side of the DC/AC converter through the second DC/DC converter to form the second power storage branch. 15

22. The power storage module of claim 21, wherein the first DC/DC converter is configured to increase the output impedance of the first power storage branch and the second DC/DC converter is configured to decrease the output impedance of the second power storage branch. 20

23. The power storage module of claim 20, wherein the AC load is an AC power grid.

24. The power storage module of claim 20, wherein the DC/AC converter is a three-phase converter and the AC load is a three-phase load, and wherein when the AC load is unbalanced, the power management unit absorbs the ripple current with a low frequency from the DC side of the DC/AC converter. 25

\* \* \* \* \*